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Laser Cooling for Heavy-Ion Fusion

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One of the critical requirements for heavy-ion fusion (HIF) is the ability to focus space-charge dominated beams onto a millimeter-size spot. However, momentum spread along the beam causes chromatic aberration which can result in a substantial fraction of the beam ions falling outside the desired spot radius. Because of the space-charge force, the remedy for correcting the chromatic aberration using sextupole magnets proves to be impractical.[1] Novel correcting schemes should therefore be sought for. Recent success in laser cooling of low-current ion beams in storage rings [2, 3] leads us to explore the possibility of applying laser cooling to HIF.

Basic Scheme -- After the beams have been accelerated to the desired energy by the recirculating induction linac,[4] we let the beams coast around at constant energy by turning the recirculator into a storage ring. The particular method used here for the HIF recirculator consists of at least two lasers (both are in the direction of beam propagation) tuned to the resonant frequency with the ion beam near the tail of the ion velocity distribution to provide the laser force F_L. In addition, there is an auxiliary force F_a, which is in the opposition direction of F_L, provided by the induction cores of the recirculator. The momentum spread along the beam can therefore be compressed by F_L and F_a in velocity space. After the compression is completed, the momentum spread is reduced.

Laser Requirement -- For efficient interaction between the laser and the beam ions, we use Ba^+ beams. We use two different lasers to pump the two transitions in the Ba^+ (P to S at 493 nm and P to D at 650 nm). Furthermore, the lasers will operate at a few times of the saturation intensity in order to increase the spread of the laser force in velocity space so that the laser can interact with a larger fraction of the beam particles.

In this paper, we will present estimates for the laser power requirements and the cooling time, and preliminary PIC simulations using the 2-1/2-D PIC code CONDOR. Potential difficulties caused by velocity space instabilities will be discussed.

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